

Math 125 Class notes Spring 2026

To accompany
Discrete Mathematics with Applications
by *Epp*

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Math 125 Formula Sheet

1.1: Variables

Definition.

A **variable** is a placeholder for something which may or may not be unknown.

Example. Is there a number with the following property: doubling it and adding 3 gives the same result as squaring it?

- Is there a number x with the property that $2x + 3 = x^2$?
- Is there a number \square with the property that $2 \cdot \square + 3 = \square^2$?

Example. No matter what number might be chosen, if it is greater than 2, then its square is greater than 4.

- No matter what number n might be chosen, if n is greater than 2,
then n^2 is greater than 4.

Example. Use variables to rewrite the following sentences:

Are there numbers with the property that the sum of their squares equals the square of their sum?

Given any real number, its square is nonnegative.

Definition.

- A **universal statement** says that a certain property is true for all elements in a set.
- A **conditional statement** says that if one thing is true, then some other thing also has to be true.
- Given a property that may or may not be true, an **existential statement** says that there is at least one thing for which the property is true.

Definition.

A **universal conditional statement** is both universal and conditional:

For every animal a , if a is a dog, then a is a mammal.

Conditional statements can be rewritten in ways that make them appear more to be purely universal or purely conditional:

If a is a dog, then a is a mammal.

All dogs are mammals

Example. Rewrite the following universal condition statement:

For every real number x , if x is nonzero then x^2 is positive.

If a real number is nonzero, then its square _____.

For every nonzero real number x , _____.

If x _____, then _____.

The square of any nonzero real number is _____.

All nonzero real numbers have _____.

Definition.

A **universal existence statement** is a statement that is universal because its first part says that a certain property is true for all objects of a given type, and it is existential because its second part asserts the existence of something:

Every real number has an additive inverse.

In the above example, note that the particular additive inverse depends on the given real number:

For every real number r , there is an additive inverse for r .

Example. Rewrite the following universal existence statement:

Every pot has a lid

All pots _____.

For every pot P , there is _____.

For every pot P , there is a lid L such that _____.

Definition.

An **existential universal statement** is a statement that is existential because its first part asserts that a certain object exists and is universal because its second part says that the object satisfies a certain property for all things of a certain kind:

There is a positive integer that is less than or equal to every positive integer.

The number one satisfies the above statement, which can also be rewritten:

There is a positive integer m that is less than or equal to every positive integer.

Example. Rewrite the following existence universal statement:

There is a person in my class who is at least as old as every person in my class.

Some _____ is at least as old as _____.

There is a person p in my class such that p is _____.

There is a person p in my class with the property that for every person q in my class, p is _____.

1.2: The Language of Sets

Definition.

- A **set** is a collection of objects.
- If S is a set, then we use
 - $x \in S$ to denote that the element x is in the set S .
 - $x \notin S$ to denote that the element x is *not* in the set S .
- The **set-roster notation** is used to denote all elements in a set between braces:

$$S = \{1, 2, \dots, 100\}$$

Here, we see that $67 \in S$, but $1337 \notin S$.

- The **axiom of extension** says that a set is completely determined by what its elements are – not the order in which they are listed.

Example.

Let $A = \{1, 2, 3\}$, $B = \{3, 1, 2\}$, and $C = \{1, 1, 2, 3, 3, 3\}$. What are the elements of A , B , and C ? How are A , B , and C related?

Is $\{0\} = 0$?

How many elements are in the set $\{1, \{1\}\}$?

For each nonnegative integer n , let $U_n = \{n, -n\}$. Find U_1 , U_2 , and U_0 .

Certain sets of numbers are so frequently referred to that they are given special names and symbols:

- N** or \mathbb{N} The set of all **natural numbers**
- Z** or \mathbb{Z} The set of all **integers**
- Q** or \mathbb{Q} The set of all **rational numbers**, or quotient of integers
- R** or \mathbb{R} The set of all **real numbers**

Note: We may additionally use superscripts to indicate further properties of these sets:

- \mathbb{Z}^+ or $\mathbb{Z}^{>0}$ The set of *positive* integers
- \mathbb{Q}^- or $\mathbb{Q}^{<0}$ The set of *negative* rational numbers
- \mathbb{R}^{nonneg} or $\mathbb{R}^{\geq 0}$ The set of *nonnegative* real numbers

Note: Different sources denote the natural numbers \mathbb{N} as \mathbb{Z}^+ or $\mathbb{Z}^{\geq 0}$.

Definition. (Set-Builder Notation)

Let S be a set and let $P(x)$ be a property that elements of S may or may not satisfy. We may define a new set to be **the set of all elements x in S such that $P(x)$ is true**. We denote this set as follows:

$$\{x \in S \mid P(x)\}$$

the set of all such that

Example. Describe each of the following sets:

$$\{x \in \mathbb{R} \mid -2 < x < 5\}$$

$$\{x \in \mathbb{Z} \mid -2 < x < 5\}$$

$$\{x \in \mathbb{Z}^+ \mid -2 < x < 5\}$$

Definition.

If A and B are sets, then A is called a **subset** of B , written $A \subseteq B$, if, and only if, every element of A is also an element of B :

$A \subseteq B$ means that for every element x , if $x \in A$, then $x \in B$.

$A \not\subseteq B$ means that there is at least one element x , such that $x \in A$ and $x \notin B$.

A is a **proper subset** of B if, and only if, every element of A is in B , but there is at least one element of B that is not in A :

$A \subsetneq B$ means that for every element x , if $x \in A$, then $x \in B$,
and there exists $x \in B$ such that $x \notin A$.

Example. Let $A = \mathbb{Z}^+$, $B = \{n \in \mathbb{Z} \mid 0 \leq n \leq 100\}$, and $C = \{100, 200, 300, 400, 500\}$. Evaluate the truth and falsity of each of the following statements.

$$B \subseteq A$$

C is a proper subset of A

C and B have at least one element in common

$$C \subseteq B$$

$$C \subseteq C$$

Example. Determine which of the following statements are true:

$$2 \in \{1, 2, 3\}$$

$$\{2\} \in \{1, 2, 3\}$$

$$2 \subseteq \{1, 2, 3\}$$

$$\{2\} \subseteq \{1, 2, 3\}$$

$$\{2\} \subseteq \{\{1\}, \{2\}\}$$

$$\{2\} \in \{\{1\}, \{2\}\}$$

Definition.

Given elements a and b , the symbol (a, b) denotes the **ordered pair** consisting of a and b together with the specification that a is the first element of the pair, and b is the second element. Two ordered pairs (a, b) and (c, d) are equal if, and only if, $a = c$ and $b = d$:

$$(a, b) = (c, d) \text{ means that } a = c \text{ and } b = d.$$

Example.

$$\text{Is } (1, 2) = (2, 1)?$$

$$\text{Is } \left(3, \frac{5}{10}\right) = \left(\sqrt{9}, \frac{1}{2}\right)?$$

Definition.

Let $n \in \mathbb{N}$ and let x_1, x_2, \dots, x_n be (not necessarily distinct) elements. The **ordered n -tuple**, (x_1, x_2, \dots, x_n) , consists of x_1, x_2, \dots, x_n together with the ordering: first x_1 , then x_2 , and so forth up to x_n . and ordered 2-tuple is called an **ordered pair**, and ordered 3-tuple is called an **ordered triple**.

Two ordered n -tuples (x_1, x_2, \dots, x_n) and (y_1, y_2, \dots, y_n) are **equal** if, and only if, $x_1 = y_1, x_2 = y_2, \dots$, and $x_n = y_n$:

$$(x_1, x_2, \dots, x_n) = (y_1, y_2, \dots, y_n) \iff x_1 = y_1, x_2 = y_2, \dots, x_n = y_n.$$

Example.

$$\text{Is } (1, 2, 3, 4) = (1, 2, 4, 3)?$$

$$\text{Is } \left(3, (-2)^2, \frac{1}{2}\right) = \left(\sqrt{9}, 4, \frac{3}{6}\right)?$$

Definition.

Given sets A_1, A_2, \dots, A_n , the **Cartesian product** of A_1, A_2, \dots, A_n , denoted

$$A_1 \times A_2 \times \cdots \times A_n$$

is the set of all ordered n -tuples (a_1, a_2, \dots, a_n) where $a_1 \in A_1, a_2 \in A_2, \dots, a_n \in A_n$:

$$A_1 \times A_2 \times \cdots \times A_n = \{(a_1, a_2, \dots, a_n) \mid a_1 \in A_1, a_2 \in A_2, \dots, a_n \in A_n\}$$

Example. Let $A = \{x, y\}$, $B = \{1, 2, 3\}$, and $C = \{a, b\}$. Find the following:

$$A \times B$$

$$B \times A$$

$$A \times A$$

How many elements are in $A \times B$, $B \times A$, and $A \times A$?

$$(A \times B) \times C$$

$$A \times B \times C$$

Describe $\mathbb{R} \times \mathbb{R}$

Definition.

Let $n \in \mathbb{N}$. Given a finite set A , a **string of length n over A** is an ordered n -tuple of elements of A written without parentheses or commas. The elements of A are called the **characters** of the string. The **null string** over A is defined to be the “string” with no characters, often denoted λ , and is said to have length 0. If $A = \{0, 1\}$, then a string over A is called a **bit string**.

Example. Let $A = \{a, b\}$. List all strings of length 3 over A with at least two characters that are the same.

1.3: The Language of Relations and Functions

Definition.

Let A and B be sets. A **relation** R **from** A **to** B is a subset of $A \times B$. Given an ordered pair (x, y) , x **is related to** y **by** R , written $x R y$, if, and only if, (x, y) is in R . The set A is called the **domain** of R and the set B is called its **co-domain**.

The notation for a relation R may be written symbolically as follows:

$$x R y \text{ means that } (x, y) \in R.$$

The notation $x \not R y$ means that x is not related to y by R :

$$x \not R y \text{ means that } (x, y) \notin R.$$

Example. Let $A = \{1, 2\}$ and $B = \{1, 2, 3\}$ and define a relation R from A to B as follows; Given any $(x, y) \in A \times B$,

$$(x, y) \in R \text{ means that } \frac{x - y}{2} \text{ is an integer.}$$

State explicitly which ordered pairs are in $A \times B$ and which are in R

Is $1 R 3$?

Is $2 R 3$?

Is $2 R 2$?

What are the domain and co-domain of R ?

Example. Define a relation C from \mathbb{R} to \mathbb{R} as follows: For any $(x, y) \in \mathbb{R} \times \mathbb{R}$,

$$(x, y) \in C \text{ means that } x^2 + y^2 = 1.$$

Is $(1, 0) \in C$?

Is $(0, 0) \in C$?

Is $\left(-\frac{1}{2}, \frac{\sqrt{3}}{2}\right) \in C$?

Is $-2 \in C$?

Is $0 \in C$?

Is $1 \in C$?

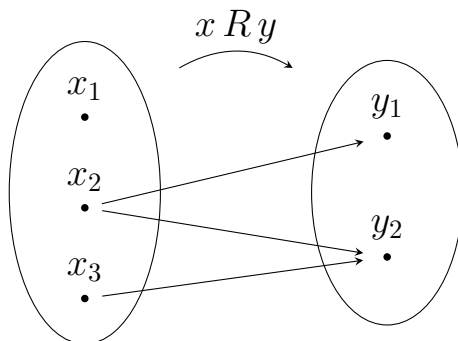
What are the domain and co-domain of C ?

Draw a graph for C by plotting the points of C in the Cartesian plane.

Definition.

Suppose R is a relation from set A to a set B . The **arrow diagram for R** is obtained as follows:

1. Represent the elements of A as points in one region and the elements of B as points in another region.
2. For each x in A and y in B , draw an arrow from x to y if, and only if, x is related to y by R .



Example. Let $A = \{1, 2, 3\}$ and $B = \{1, 3, 5\}$ and define relations S and T from A to B as follows: For every $(x, y) \in A \times B$,

$(x, y) \in S$ means that $x < y$

$T = \{(2, 1), (2, 5)\}$.

Draw arrow diagrams for S and T



Definition.

A **function** F from a set A to a set B is a relation with domain A and co-domain B that satisfies the following two properties:

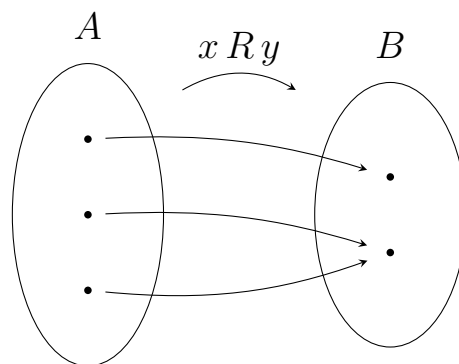
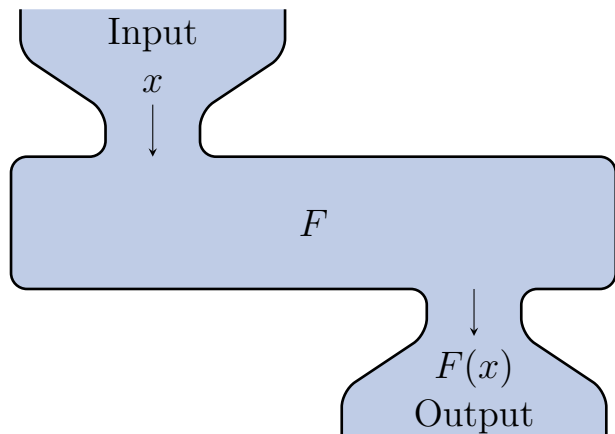
1. For every element x in A , there is an element y in B such that $(x, y) \in F$.
2. For all elements x in A and y and z in B ,

if $(x, y) \in F$ and $(x, z) \in F$, then $y = z$.

Note: A relation from A to B is a function if, and only if,

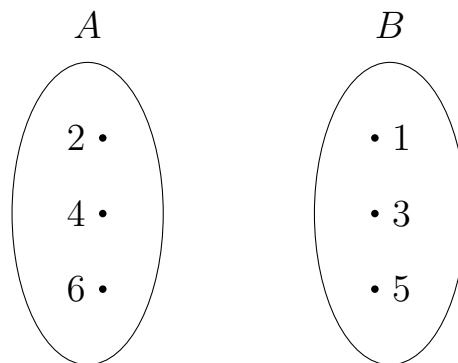
1. Every element of A is the first element of an ordered pair of F
2. No two distinct ordered pairs in F have the same first element.

Note: If A and B are sets and F is a function from A to B , then given any element x in A , the unique element in B that is related to x by F is denoted $F(x)$, which is read “ F of x ”.

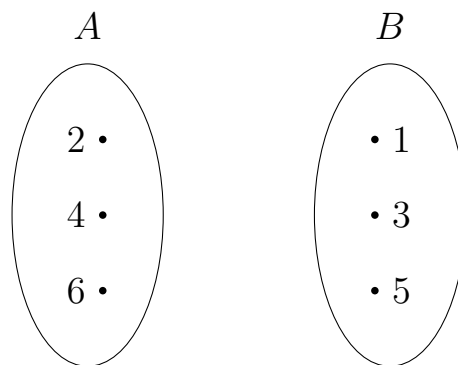


Example. Let $A = \{2, 4, 6\}$ and $B = \{1, 3, 5\}$. Which of the relations R , S , and T defined below are functions from A to B ?

$$R = \{(2, 5), (4, 1), (4, 3), (6, 5)\}$$



For every $(x, y) \in A \times B$, $(x, y) \in S$ means that $y = x + 1$.



T is defined by the arrow diagram

